STATE ENGINEERING EXPERIMENT STATION

The Research Engineer

GEORGIA SCHOOL OF TECHNOLOGY

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The Research Engineer

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OUR DEBUT

With this issue is born THE RESEARCH ENGINEER, the "voice" of the State Engineering Experiment Station of the Georgia School of Technology. For some time now the Station has been publishing technical bulletins in summary of its research achievements and reprints of those articles on Georgia Tech research which have appeared in various technical journals. These issues will be continued and expanded, but we have long felt the need for a periodical bulletin to complete the publication pattern.

This bulletin, we hope, will be *your* bulletin. It will help to keep alumni and faculty abreast of the research and technical activities of Georgia Tech and, as well, of the technical achievements of members of their own groups. It will bring all of these items to the attention of Georgia industry and will thus, through wider dissemination of information, aid in the development of Georgia and the South.

This issue may or may not be typical of those to follow, depending upon your desires. In one case only have we indicated the start of a series or department — the "Report From the Library," although others are planned for future issues.

On all of these matters we want your advice, and we urgently solicit your response to WHAT WOULD YOU LIKE, which appears on page 24. The success of this bulletin will chiefly be measured by its contribution to your useful information. If we fail in this respect, we shall be wasting both your time and ours, and time is always "of the essence."—Gerald A. Rosselot.

Research at Tech We invite your particular attention, in this issue, to two articles which deal with the specific role of Georgia Tech in the research picture of the southeast and the nation. The first of these, by President Van Leer, brings into sharp focus the industrial research background and needs of this area, while the second, on the newly-organized Georgia Tech Research Institute, lists the fundamental details of the industrial research picture of the School.

Science is now the topic of much public and government discussion; its achievements are no longer known only to the scientists themselves. There is little doubt that the wartime level of research, high as it was, will shortly be surpassed. Georgia Tech possesses unusual facilities for the performance of both industrial and fundamental research, and it is obviously desirous of making these facilities known and available to those who may need them.

RESEARCH AND THE SOUTHEAST*

By BLAKE R. VAN LEER
President, Georgia School of Technology

Until recent times, the Southeast has been an agricultural region, and its industrial and technical research activities have ranked, almost per se, after those of the northern and western states. During the period from 1941 to 1945, however, the research activities of the Southeast have increased greatly in number and in scope, along with the accelerated industrial growth of the region.

This is completely understandable, for research has made possible many, if not most, of the outstanding industrial developments of the last 25 years. Indeed, such industries as the aeronautical, automotive, chemical, and electrical may almost be said to have actually been born and nurtured through research. Certainly during the recent war, industry found increased efficiency and output to be directly related to research and to those men of alert minds who are ever vigilant for new applications of scientific and technological advances.

GROWTH OF RESEARCH

In order to obtain a better picture of what we have and can have in the Southeast, it seems necessary to review the growth of American research as a whole. Since war restrictions caused a veritable blackout of facts and figures concerning research activities and organizations during the past five years, however, it will be necessary to rely chiefly upon material available just before the war.

The first real industrial research departments in companies were not organized until after 1900, and the forerunner of the present group of 47 state engineering experiment stations was formed in 1903 at the University of Illinois. Logically, the first companies to make research a part of their business were those process industries whose operations were based on science. In turn, the creation of research laboratories brought about a closer relationship between industry and the engineering colleges, because of the former's demand for more technical graduates to man the laboratories and the new manufacturing plants created by these laboratories.

The first engineering experiment station in the Southeast, at the Georgia School of Technology, was authorized by the state legislature in 1919. Since that time, similar stations have been established at colleges and universities in each of the eight other Southeastern states. In a recent report,[4] Dean J. H. Lampe, North Carolina State College, has stated: "The Engineering Experiment Stations are making worthwhile contributions in fundamental research as their principal business, but are also rendering yeoman service to the industrial and economic welfare of their States by carrying out many projects in applied research. Such projects are aiding in the development of natural resources and in providing better ways to manufacture existing articles as well as bringing forth new processes and thus helping to establish new industries."

In 1920, there were 307 industrial research laboratories in the United States, but, of this number, only nine were located in the Southeast. By 1938, the numbers were 2,237 and 119, respectively,[5] and by 1940, these figures were 2,350 and 177.[2] The establishment of research laboratories by many war industries in this area; the formation in Georgia and other southern states of new chemical and metallurgical companies and attendant research laboratories; and the belated recognition of the importance of research in their organizations by some Southeastern companies have all served to increase the number and scope of national and regional laboratories.

Just before the war, more than $300,000,000 was being spent annually on technical and industrial research. According to figures compiled by the National Research Council in 1938, research expenditures for that year amounted to $100,000,000-$150,000,000 by industry and business, $65,000,000 by the Federal Government, and $50,000,000 by the universities and colleges.[1] Based on these figures, it can be assumed that our institutions of higher learning, then at least, carried 20 per cent of the burden of research expenditures.

Sometimes in conjunction with colleges and universities, and sometimes separately, a group of "industrial research institutes" have been developed. The first one, established in

* *Presented at the Southern Machinery and Metals Exposition, April 23, 1946.*

1911 through the foresight of Dr. Robert Kennedy Duncan and with the financial assistance of the Mellon brothers, was the Mellon Institute of Industrial Research in Pittsburgh. Another is the Battelle Memorial Institute in Columbus, Ohio, which started operations in 1929. In the North, other research institutes have been established at colleges and universities, such as the Institute of Paper Chemistry at Lawrence College in 1929, the Purdue Research Foundation at Purdue University in 1930, and the Ohio State University Research Foundation. In the Southeast, we find the Industrial Research Institute at the University of Chattanooga; the Southern Research Institute at Birmingham, Alabama; the Callaway Institute at LaGrange, Georgia; the Herty Foundation at Savannah, Georgia; the Institute of Textile Technology at Charlottesville, Virginia; the Institute of Industrial Research of the University of Louisville, in Kentucky; and the Georgia Tech Research Institute at the Georgia School of Technology, in Atlanta.

Just as in the field of engineering we have consulting engineers, so in the field of industrial research there are private laboratories which are termed commercial research and testing laboratories. As early as 1886, Dr. Arthur D. Little, in partnership with Roger B. Griffin, opened a laboratory in Boston to advise industry ". . . as chemical engineers, analytical and consulting chemists, and for doing expert and general laboratory work . . ." Since that time, many other groups of this type have been formed in this country. For example, among those which are making valuable contributions to industrial research is the Barrow-Agee Laboratories, whose main offices are located in Memphis, Tennessee, with branches in Tennessee and Mississippi. Many industries depend upon these testing laboratories to check the results of operations and the specifications of materials. Among the first established in this country were the Electrical Testing Laboratories, New York, N. Y.; the Robert W. Hunt and Co., Chicago, Ill.; the Pittsburgh Testing Laboratory, Pittsburgh, Pa.; and the United States Testing Company, Hoboken, N. J. A few such laboratories are located in the Southeast; one of these is Law & Co. of Wilmington, N. C., with branches in Atlanta and Cordele, Ga.

SPONSORS OF INDUSTRIAL RESEARCH

What companies in the United States are sponsoring and supporting industrial research? According to a report made in 1938,[5] forty-five at that time employed more than half of the total research personnel, while six of these companies; namely, du Pont, Eastman Kodak (including Tennessee Eastman), B. F. Goodrich, Hercules Powder Co., Monsanto Chemical, and U. S. Rubber, maintained research laboratories in the Southeast. This same report lists the number of research personnel, showing their percentage distribution by industrial groups, and, for a selected group, the number of research workers for 10,000 wage earners. These figures are shown in Table I.

It will be noted from Table I that the chemical and allied industries led the field in the percentage distribution. Next in order were petroleum; electrical communication; electrical machinery, apparatus and supplies; other machinery industries; and rubber products. It is evident that the three big industries, chemical, petroleum, and electrical (including communication, radio, machinery and utilities), account for most of the peacetime research work carried on in the United States. These industries have recognized the fact that research promotes their growth and greatly increases their earning power. Compared to some of the others, such industrial groups as rubber products; stone, clay and glass products; and non-ferrous metals and products also rank high in their use of research.

The third column in Table I shows the estimated research expenditures per $100 value added by manufacture in 1937. On the average, manufacturing industries spent for industrial research only $0.64 per $100 value.[2] World War II was responsible for raising this average, and the civilian economy will benefit thereby through new and improved merchandise. But many companies, today, especially those here in the Southeast, have yet to realize the possibilities of research for expanding their markets and putting their businesses on a profitable basis. Dr. Frank Jewett,[3] one of the outstanding research engineers of this country, pointed out in 1945 that "because the methods which science uses, both fundamental and applied, are so powerful and certain

TABLE I
DISTRIBUTION OF RESEARCH PERSONNEL AND EXPENDITURES, BY INDUSTRIAL GROUPS, 1938

INDUSTRIAL GROUPS	Per Cent Research Personnel Distribution (1938)	Ratio of Research Personnel to 10,000 Wage Earners (1937)	Research Expenditures Per $100 Manufacturing Value Added (1937)	Per Cent of Gross Sales Used for Research
Chemicals and allied products	21.5	303	$2.38	3 to 4
Petroleum and its products	11.4	207	1.13	0.5
Electrical communications	9.5	103		
Electrical machy., apparatus and supplies	6.8	118	1.67	
Consulting and testing laboratories	6.0			
All other machinery	5.2	32	.50	2
Rubber products	5.1	173	2.73	0.875
Motor vehicles, bodies, and parts	4.4	41	1.08	
Agricultural implements (incl. tractors)	4.1		2.90	
Miscellaneous	4.0			3
Iron and steel and their products (not machinery)	3.5	15	.20	1
Food and kindred products	3.2	16	.19	0.52
Stone, clay and glass products	3.2	47	.72	1.5
Non-ferrous metals and products	2.7	44	.62	1
Radio apparatus and phonographs	2.5	232		
Utilities (gas, light, and power)	2.2	32		
Paper and allied products	1.7	28	.39	
Trade associations	1.3			
Textiles and products	0.8	2	.06	0.5
Forest products	0.4	3	.07	2
All other transportation equipment	0.3	9	.05	2
Leather and its manufacture	0.2	2	.06	0.3
	100.0			

in achieving the ends sought, money spent through well-organized research and development departments is the least risky and potentially the most profitable of all the expenditures in which industry ventures capital."

Dr. Karl T. Compton in 1940,[2] through the cooperation of the National Association of Manufacturers, established the figures shown in the fourth column, which indicates research expenditures by industries compared to their gross sales income.

PERSONNEL

Who are operating the industrial research laboratories of the United States? F. S. Cooper[2] in 1940 estimated that there were more than 70,000 industrial research personnel. Of this number, 52.2 per cent were scientists and engineers, while the balance included other technical, administrative, clerical, and maintenance personnel. A detailed breakdown is shown in Table II.

From various sources it has been estimated that the cost per man-year of research averages between $4,000 and $5,000 per year. Using the lower figure and company earning records for 1940,[2] the ratio of the research expenditures of an average company to its sales is 0.6 per cent, and the ratio to its net income is six per cent.

The cost of individual research projects varies widely, ranging from a few hundred dollars to hundreds of thousands. In university research,[1] it was found in 1940 that the average technical project takes approximately four years to complete at an individual cost of $4,000. A project for a doctorate degree averages about 2½ years at a cost of $2,500. It must be pointed

TABLE II

OCCUPATIONAL CLASSIFICATION OF INDUSTRIAL RESEARCH PERSONNEL, 1940

Type of Personnel	Number	Per Cent
Professionally trained:		
Chemists	15,700	22.4
Physicists	2,030	2.9
Engineers	14,980	21.4
Metallurgists	1,955	2.8
Biologists and bacteriologists	979	1.4
Other professional	909	1.3
Total professional	36,553	52.2
Other technical	16,400	23.4
Administrative, clerical, maintenance, etc.	17,080	24.4
Total	70,033	100.0

out, incidentally, that these are prewar cost figures and that present-day costs are higher.

From conversations with hundreds of Southern industrialists, I am convinced that they recognize the value of industrial research to their individual industries. With the end of the war and an easing of materials required for the construction and outfitting of laboratories, many of them are seriously considering the establishment of research departments. Some of them have stated that the only factor holding them back is a lack of properly-trained technical and scientific personnel.

Our engineering schools in the Southeast have been doing a wonderful job in training such personnel throughout the years. But, say some of our Southern contemporaries, these men have left and gone north to the industrial states of New York, New Jersey, Pennsylvania, Delaware, Michigan, Illinois, Indiana, and Ohio. Let me quote a few facts and figures that should be of interest. In a recent survey at the Georgia School of Technology, it was found that out of 13,537 alumni now living, more than 50 per cent were living in Georgia, with more than 80 per cent in the Southeast. It is true that many of these men went north upon graduation, to obtain experience, but they have returned and are now utilizing their training and skills for the advancement of the Southland.

Engineering graduates are now so much in demand that each of the recent graduating seniors at the Georgia School of Technology has averaged about one dozen job offers from all parts of the country. The majority of the boys from the southeastern states, however, have accepted jobs here because their chances of developing professionally and their opportunities for advancement are just as good in the South, where our industries are growing in stature and developing in scope. For example, recent statistics indicate that, right in Atlanta, there is more industrial construction per capita going on than in any other major city in the United States.

Those scientists and engineers who desire more training in the fields of research before going into the laboratories of the Southeast can obtain such training right at our own southern colleges and universities. Today, these institutions are engaging in all phases of pure and applied research (see Table III), thus providing a great proving ground for the industrial research workers of tomorrow.

No industry or institution can advance unless it has the facilities and the personnel. Being better acquainted with the Georgia School of Technology than with any other similar institution in the Southeast, let me tell you what we are doing along these lines. Our quarter-million-dollar Research Building, around which all research at Georgia Tech centers, will be expanded within the next few months with a $150,000 addition and, among many other modern instruments and equipment, will house a $100,000 A.C. Network Analyzer and Calculator. In our Electrical Engineering Department, we have just installed a complete electronics laboratory. We are in process of installing a modern fluid-flow laboratory in the Civil Engineering Building. Our new gage laboratory in the Mechanical Engineering Department contains many of the new blocks, gages, and instruments which were developed during the war by the Armed Forces.

In our Graduate Division, we have instituted a series of awards for graduate students who are desirous of pursuing a career in research but cannot do so for financial reasons. These graduate students are given ample opportunity and time to devote to applicable research projects. Faculty members who

TABLE III

COLLEGE RESEARCH LABORATORIES IN THE SOUTHEAST

ALABAMA

Alabama Polytechnic Institute, Auburn, Ala.
Chemical engineering and chemistry.

University of Alabama, University, Ala.
Aeronautical, chemical, civil, electrical, industrial, mechanical, metallurgical, mining, and sanitary engineering.

FLORIDA

University of Florida, Gainesville, Fla.
Ceramic research, farm machinery, hurricane location, lime rock and concrete, sanitary engineering, waste material recovery, and wood utilization.

GEORGIA

Georgia School of Technology, Atlanta, Ga.
Aeronautical, architectural, ceramic, chemical, civil and highway, electrical, mechanical, and textile engineering; industrial design; physics; and chemistry. Also industrial engineering, industrial management, and engineering mathematics.

KENTUCKY

University of Kentucky, Lexington, Ky.
Aeronautical, air conditioning, steam power plant, electronics, highway, ore preparation and dressing, and physical metallurgy.

University of Louisville, Louisville, Ky.

MISSISSIPPI

Mississippi State College, Starkville, Miss.

NORTH CAROLINA

North Carolina State College, Raleigh, N. C.
Ceramic, chemical, civil, electrical, geological, and mechanical engineering; and physics.

SOUTH CAROLINA

Clemson Agricultural College, Clemson, S. C.
Electronics, chemistry, soils, minerals, structural unit studies, clays, water power utilization, and ultra-high frequency investigations.

TENNESEE

University of Tennessee, Knoxville, Tenn.
Chemical engineering, electronics, engineering materials, mechanical engineering, metallurgy, and soils.

VIRGINIA

Virginia Polytechnic Institute, Blacksburg, Va.
Aerodynamics, ceramic engineering, electronics, chemical engineering, engineering materials, fuel utilization, heat transfer, industrial waste, production planning and control, steam pollution, timber engineering.

show an aptitude for research work are relieved partly or entirely from teaching duties so that they can give time to research.

It has been pointed out that one of the most valuable adjuncts to any research program is an up-to-date and complete technical library. The Georgia Tech Library collection has been expanded almost 50 per cent in the last two years and today is rated by people who know as the best in engineering and technical usefulness in the South.

Industrial research has finally arrived in the Southeast, making possible a higher standard for its people, increasing industrial development of its many natural resources, and providing a better education for all by adapting engineering and research techniques to agriculture, to industry, and to the homes, thus enabling the people to think, live and grow.

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GEORGIA

Georgia School of Technology, Atlanta, Ga.
Aeronautical, architectural, ceramic, chemical, civil and highway, electrical, mechanical, and textile engineering; industrial design; physics; and chemistry. Also industrial engineering, industrial management, and engineering mathematics.

KENTUCKY

University of Kentucky, Lexington, Ky.
Aeronautical, air conditioning, steam power plant, electronics, highway, ore preparation and dressing, and physical metallurgy.

University of Louisville, Louisville, Ky.

MISSISSIPPI

Mississippi State College, Starkville, Miss.

NORTH CAROLINA

North Carolina State College, Raleigh, N. C.
Ceramic, chemical, civil, electrical, geological, and mechanical engineering; and physics.

SOUTH CAROLINA

Clemson Agricultural College, Clemson, S. C.
Electronics, chemistry, soils, minerals, structural unit studies, clays, water power utilization, and ultra-high frequency investigations.

TENNESEE

University of Tennessee, Knoxville, Tenn.
Chemical engineering, electronics, engineering materials, mechanical engineering, metallurgy, and soils.

VIRGINIA

Virginia Polytechnic Institute,
Blacksburg, Va.
Aerodynamics, ceramic engineering, electronics, chemical engineering, engineering materials, fuel utilization, heat transfer, industrial waste, production planning and control, steam pollution, timber engineering.

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AREA ECONOMIC STUDIES

By JOSEPH B. HOSMER
Fellow in Industrial Economics
State Engineering Experiment Station
Georgia School of Technology

The Northeast Georgia Area Economic Study, the seventh in a series, has just gone to the printer. This 292-page volume was prepared to describe three things about the 16 northeast Georgia counties with which it is concerned: the available economic resources of the area, both natural and human; the economic problems which exist in the area; and the existing economic opportunities which are capable of development into profitable industries.

With the completion of this volume, the Industrial Economic Research Staff of the State Engineering Experiment Station, under the direction of Professor H. E. Dennison, has analyzed 105 counties in Georgia and, as a necessary complement to the various areas, 12 counties in South Carolina, two in Florida, and one in Alabama.

The series has as its basic objective the assembly and analysis of such pertinent material as is useful in deciding whether or not a particular type of industry should be located in a particular part of Georgia. It was begun at the request of the Macon Chamber of Commerce, which felt a need for an authoritative source book on the area surrounding Macon for use in preparing industrial prospectuses.

Following the completion of the Macon study, requests for similar reports were received from chambers of commerce or local groups in the areas surrounding Augusta, Waycross, Valdosta, Albany, Rome, and Northeast Georgia. Figure 1 shows the counties included in each of the studies.

For each of these area economic studies, the sponsoring group has underwritten the direct costs, while the State Engineering Experiment Station, serving as co-sponsor, has carried the burden of the necessary overhead. In every case, the chamber of commerce or other sponsoring group has made the first move, since it has been the belief of Dr. G. A. Rosselot, Director of the Station, and Professor Dennison that, unless an active interest in knowing the economic facts was already in existence in an area, there would be little likelihood of any constructive action. As has been pointed out in several of the reports, "the prosperity of Georgia is simply the sum of the various local 'prosperities' which exist in the several sections of the state." Each local prosperity, in turn, is dependent upon the manner in which existing human and natural resources are utilized. The future of each area in Georgia depends on what forms of action the people living in the area take for the economic utilization of these resources.

POSTWAR PROSPECTS

The postwar period gives promise of continuing the high productive pattern with which the United States amazed the world during the war. Reconversion in Georgia and the Southeast has been more rapid than elsewhere, since the number of required job changes has been smaller than in many other areas, either relatively or as a total. The volume of goods produced, while larger than prewar, still lags behind pent-up consumer demand. The Southeast is in a favorable position to increase its productive service to the nation. Manufacturing in Georgia appears to be definitely increasing its relative position in the national economy. Among the factors justifying this view are:

1. The authorization by Congress of the Coosa River and Savannah River development projects.
2. The class-rate decision of the Interstate Commerce Commission.
3. The recently-announced postwar expansion of automobile assembly and manufacture in the Atlanta area.

The Southeast has for years had a more favorable power rate than the United States average, and manufacturers in the Southeast have therefore used more power per wage-earner than this average. The Savannah River and Coosa River developments will add to the available power at a highly favorable rate and will more than double the

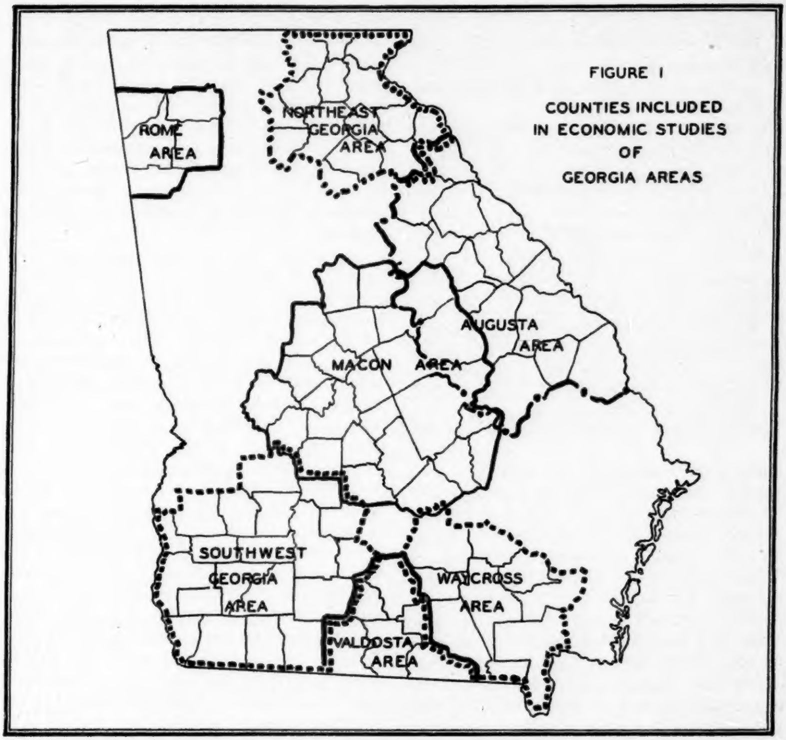

FIGURE I

COUNTIES INCLUDED IN ECONOMIC STUDIES OF GEORGIA AREAS

total power available in Georgia.

The first two factors were contributory to the recent decisions of major automotive manufacturers to expand their assembly and manufacturing operations in Atlanta. This move, in turn, creates numerous opportunities for the establishment in Georgia of parts manufacturing plants to service this expansion.

Manufacturing employment in Georgia during the war period rose to almost twice the 1939 level; manufacturing payrolls were approximately tripled, as shown by Table I. The following data on manufacturing are quoted from the reports.

So far as Georgia is concerned, trends of long standing indicate that the growth shown in the preceding table may be expected to continue. Between 1919 and 1939, manufacturing employment increased from 1.36 per cent of the national total to 2.0 per cent. The relative position of wage payments in manufacturing over the same period rose from 0.96 per cent of the national total to 1.19 per cent.

Each report in the area economic series is intended to be a source of information and ideas. The value lies in the assemblage of facts and in their presentation in a form which, it is hoped, will stimulate constructive thinking on the part of those who use them. Only the facts and general conclusions can be presented in these reports; the individual must make his own decisions about particular situations.

STUDY PATTERNS

While no two of the areas proved to have exactly the same economic problems, it has been possible to employ a common

TABLE I

COMPARISON OF MANUFACTURING EMPLOYMENT AND PAYROLLS FROM 1939 TO 1944 COVERED BY UNEMPLOYMENT INSURANCE

Year	Average Number Employed	Total Payrolls	Average Per Employee
1939	183,000	$150,259,000	$ 821
1940	192,000	161,550,000	841
1941	231,000	224,688,000	973
1942	258,000	300,953,000	1,166
1943	297,000	440,316,000	1,483
1944	301,000	509,738,000	1,693

Source: Georgia Labor Department, Unemployment Division. The data include only firms engaged in manufacturing and covered by unemployment insurance (8 or more employees).

pattern in organizing the material. This pattern includes the following topics: History, Weather, Population, Housing, Labor Force, Income, Agriculture, Industry, Taxes, Geology (largely integrated with Industry), Water Resources, and summaries for each county.

The inclusion of Agriculture as a major topic in a study whose primary objective is to promulgate a sound industrial development may appear surprising to a few engineering specialists. However, in most Georgia counties, agriculture is the major activity, and a sound view of the economy is impractical without its evaluation. Also, many important industries derive their raw materials from agriculture, and their introduction will affect the agricultural labor force; consequently, it is necessary to consider all phases of the economy in order to avoid suggestions which might do more harm than good.

In general, the agricultural section of each study contains a summary which discusses the long-term trends; a classification of the counties in the area on the basis of the relationship between the farms in each county, grouped by farm size and by farm income; a discussion of the characteristics of agriculture in the area; and an evaluation of the livestock opportunities.

The Industry section begins with a discussion of the industry pattern which existed in 1939 (the last available census), followed by a discussion of such industries as appear to be desirable additions to the area. The industry-by-industry discussions provide the available information on raw materials, power, labor, markets, and profits, with the idea of making available those facts which a prospective entrepreneur must know in a preliminary way before deciding whether or not to make a more specific engineering and market study of a particular location.

STATISTICAL TECHNIQUES

Several interesting statistical techniques are employed in developing the industrial and agricultural sections. In the industry section, wherever possible, the probability of a profitable operation is evaluated from standard census-of-manufactures figures by a formula developed by previous work of the Industrial Economic Research Staff.

The Census of Manufactures for 1939 classifies all industries in the United States into 447 industry types. In some cases, the census consolidates in a single report diverse processes with similar end-products. For the vast majority of industries, however, the probable variations between individual plants is not so great that comparisons can not be made on the basis of internal ratios between two areas for the same industry, as well as between one type and another type in the same area or different areas.

The statistical method by which these ratio comparisons can be made yields seven pertinent figures, derived by dividing the sum of factory wages and salaries into the appropriate total. These figures show that, for each expenditure of $100 in plant salaries and wages, a specific industry in a specific state: (1) produces a certain value of product; (2) consumes a certain value of materials, supplies, containers, fuel, and electricity; (3) pays a definite amount of plant salaries; (4) creates a specific additional value (value added); and (5) yields a specific gross margin, obtained by subtracting $100 (the unit of wages and salaries) from the value added. It is also possible, usually, to calculate (6) the value of fuel consumed and (7) the value of purchased electricity consumed for each $100 of wages and salaries.

The first four statements are derived directly from the usual figures reported in

the census for industries by states,* while the other three are derived either from other tables or from additional calculations. The most significant of these values are those for value added and for gross margin. The 1939 average gross margin for all industries in the United States is $172; for the Southeast, $121; for Georgia, $101. Types of areas which are above this average will usually contribute more to the prosperity and standard of living of the community than those which are below.

For the agricultural section, two statistical techniques have been developed. The first, which deals with the classification of counties on the relationship between total income and size of farm, was devised with the assistance of Major J. William Firor, Head of the Department of Agricultural Economics in the College of Agriculture at the University of Georgia.

The second special agricultural technique, devised by Professor Frank King, Assistant Professor of Farm Management in the College of Agriculture, provides a means of estimating the capacity of counties and areas to support livestock.

Both from an industrial and from an agricultural viewpoint, Georgia is a state possessing great diversity of resources. As mentioned, no two areas already studied were alike. Obviously, therefore, that it is particularly dangerous to draw broad economic generalities and then attempt to apply them to the development of all parts of the state.

TECHNICAL CONSULTANTS

Technical consultants who have contributed to this series of economic evaluations of Georgia areas include the following members of the Georgia Tech faculty: Professor H. B. Duling, Dr. Lane Mitchell, Professor Charles Wysong, Professor G. N. Sisk, and Dr. Paul Weber.

Emory University very graciously made available Professor Arthur C. Munyan, Associate Professor of Geology, to prepare geologic material while Dr. Mitchell was in the Navy. Frank P. King and Major J. William Firor, Sr., Agricultural Economists at the College of Agriculture, University of Georgia, wrote much of the agriculture sections.

Through the assistance of all these men, the Industrial Economic Research Staff of the State Engineering Experiment Station has been enabled to do its share in helping to foster the industrial development of Georgia and the South. Sound development requires facts, not theories, and facts are not always at hand or of obvious meaning. It is for these reasons that the Area Economic Studies are of value to their sponsors, to industry as a whole, and thus to Georgia and the nation.

ATOMIC WEIGHTS FROM DENSITY AND X-RAY DATA

By DWIGHT A. HUTCHISON

Research Associate, State Engineering Experiment Station

and Graduate School

Georgia School of Technology

Atomic weights have played an important role in the drama of scientific development. Our ideas today concerning the ultimate structure of matter are closely related to work on their refinement. A study of the great discoveries of science reveals one common subject of investigation; namely, that of atomic weights.

At Georgia Tech, therefore, we have felt it desirable to conduct research on a relatively new method for determining atomic weights, with the end view of refining existing data.

This new method of determining atomic weights comprises a comparison of the molecular weights of two crystalline substances by means of a combination of precise density and X-ray data. For the com-

*For 1939, the salary item is not reported for counties, so that comparable calculations cannot be made at the county level.

parison of the molecular weights of two crystalline substances, there must be known the values of the absolute densities, the ratio of the true X-ray grating spaces, and the arrangement of molecules in the unit cell of each substance. The comparison can be expressed by means of the relationship,

$$M_1 = M_2 \, (p_1/p_2) \, FRg^3 \qquad (1)$$

The numerical subscripts refer to the two crystalline substances whose molecular weights are compared; M is a molecular or atomic weight; p is a density; F is a factor determined by the crystal structures; and Rg is the ratio of the true X-ray grating spaces of the two crystals.

C. A. Hutchison and H. L. Johnson[1] have used equation (1) to compare the molecular weights of lithium fluoride and calcite. With the assumption of the atomic weights of calcium, carbon, and lithium, they were able to obtain an atomic weight for fluorine. H. L. Johnston and D. A. Hutchison[2] have obtained an atomic weight for fluorine, utilizing the data on lithium fluoride and sodium chloride and assuming the atomic weights of lithium, sodium, and chlorine. C. A. Hutchison[3] has calculated the atomic weight of calcium, utilizing the data on calcite and diamond and assuming the atomic weight of carbon. From this value for calcium and that assumed for carbon, he has calculated the atomic weight of fluorine. The writer[4] has reported values for the atomic weights of calcium and fluorine, calculated from the X-ray and density data for calcite, lithium fluoride, and potassium chloride. Recently, he has published[5] the results of further refinements in the atomic weights of calcium and fluorine, utilizing the density and X-ray data on the crystals of lithium fluoride, calcite, diamond, sodium chloride, and potassium chloride.

The Rg's used in the latter work were calculated directly from the primary data, the X-ray reflection angles. Since the values of the Rg's, F's, and p's have been determined with great precision for the five

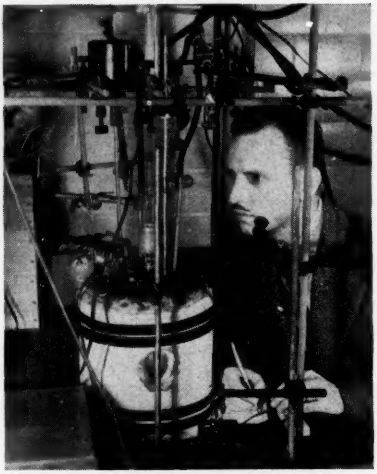

Figure 1. Density apparatus. Near the observer's face is shown the telescope through which the crystal behavior is observed.

crystalline substances used in the latter work, it was possible to compare the molecular weights of these substances with great precision. For a detailed account of these atomic weight computations, the reader may consult the original articles.

If sufficient X-ray and density data were available, it would be possible to compose a system of X-ray-density atomic weights which would be independent of those from chemical determinations. Since sufficient experimental data has as yet not been accumulated to serve as a basis for an independent set of atomic weights, however, we may refer to the results obtained as X-ray-density-chemical atomic weights.

The purpose of the present article is to give a survey of the method used in determining precise densities of crystalline substances, the method of computing atomic weights from these densities and X-ray data, and, finally, the results which have been obtained for atomic weights thus far determined.

METHOD OF DENSITY DETERMINATION

For density determination, the writer has developed the "crystal suspension" method

[1] C. A. Hutchison and H. L. Johnston, *J. Am. Chem. Soc. 63*, 1580 (1941)

[2] H. L. Johnston and D. A. Hutchison, *Phys. Rev. 62*, 32 (1942).

[3] C. A. Hutchison, *J. Chem. Phys. 10*, 489 (1942).

[4] D. A. Hutchison, *Phys. Rev. 66*, 144 (1944).

[5] D. A. Hutchison, *J. Chem. Phys. 13*, 383 (1945).

TABLE I

SAMPLE SUSPENSION MEASUREMENTS ON THREE CRYSTALS OF KC1*

Measurement 1	Measurement 2	Measurement 3
1.980 R	1.995 F	1.980 R
1.997 F	1.980 R	1.995 F
1.985 R	1.995 F	1.985 R
1.993 F	1.985 R	1.992 F
1.987 R	1.992 F	1.986 R
1.995 F	1.988 R	1.990 F
1.986 R	1.993 F	1.985 R
1.991 F	1.988 R	1.990 F
1.987 R	1.992 F	1.986 R
1.991 F		1.990 F
1.987R		
1.991 F		
SUSPENSION TEMPERATURE		
1.989 ± 0.002	1.990 ± 0.002	1.988 ± 0.002

* Temperatures in °C. R = rising temperatures; F = falling.

of Lewis and MacDonald[6] into one of high precision. This procedure is essentially the "free submerged float" method[7] which has been employed extensively for the isotopic analysis of water.

First of all, the method requires the selection of a suitable liquid, one which has about the same density as that of the crystal whose density is to be measured. In addition, the liquid should not react chemically with the crystal. The crystal is submerged in the liquid, and the temperature of the liquid is then adjusted so that the crystal is suspended. When this has been effected, the density of the crystal is the same as that of the liquid, and, if the liquid has been calibrated for change of density with temperature, we have a means of obtaining the density of the crystal.

Suspension of crystals was carried out in a glass-stoppered tube immersed in a small water bath whose temperature was manually controlled to within 0.001° C. The crystal was illuminated through small windows in the walls of the water bath and was observed against the cross-hairs of a telescope. Temperatures were read on a Beckmann thermometer calibrated by the Bureau of Standards. A picture of the density-suspension apparatus is shown in Figure 1.

The suspension temperatures were determined in the following manner. The temperature of the water bath was alternately raised and lowered to get rising (R) and falling (F) temperatures of the crystal. The temperature interval between R and F was gradually narrowed until the same interval of 0.004° to 0.005° C. could be passed over at least four times with four reversals of motion. The temperature, T, at the midpoint of this interval was then taken as the suspension temperature ± 0.002° C. In Table I are some suspension records on three crystals of purified potassium chloride which serve to illustrate the sensitivity and reproducibility obtained.

At first, some difficulty was experienced from rapid drift in the apparent temperature of suspension. This was observed when the approach to equilibrium was begun with the initial temperature of the water bath several tenths of a degree away from the correct suspension temperature and is probably ascribable to convection currents in the suspension liquid, resulting from rapid variations in the temperature of the bath. This is illustrated in Figure 2 for a crystal for which the bath was purposely held, first, at a temperature a few tenths of a degree above the crystal suspension temperature before suspension bracketing was begun (curve I), then, secondly, at a temperature somewhat below the suspension temperature before measurements were taken (curve II). This difficulty was not encountered when the bath was held at a temperature within a few hundredths of a degree of that necessary for suspension for several minutes prior to measurement. A rough estimate of the suspension temperature in advance of the measurements thus made it possible to eliminate the annoyance illustrated in the graph for most of the later analyses.

In Figure 3 are shown two views of a crystal of potassium chloride as seen by the observer against the cross-hairs of the telescope. The left view shows the crystal above the cross-hair line at a time when the temperature of the bath was below that of the

[6] G. N. Lewis and R. T. MacDonald, *J. Am. Chem. Soc. 58*, 2519 (1936).

[7] G. N. Lewis, *J. Am. Chem. Soc. 55*, 1297 (1933); G. N. Lewis and R. T. MacDonald, *J. Chem. Phys. 1*, 341 (1933).

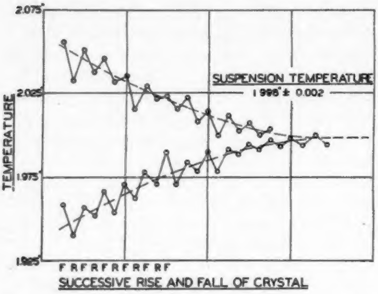

Figure 2. Plot of successive rising and falling temperatures for a crystal of KCl when the thermostat was held above (I) or below (II) the suspension temperature for some time before measurements were begun.

suspension temperature of the crystal. The right view shows the crystal below the cross-hair line when the temperature of the bath was above that of the suspension temperature of the liquid.

The density of crystals has thus been determined with great precision through observation of the narrow temperature limits that distinguish the rise and fall of individual crystals, submerged in a suitable suspension liquid whose density-temperature coefficient was determined in a previous calibration.

PREPARATION AND CALIBRATION OF THE SUSPENSION LIQUID

As mentioned, a liquid has to be found for the crystal suspensions which has the proper density, the proper change of density with temperature, and the necessary chemical inactivity and stability. For our work on crystal densities having values from about 1.9 to 2.7 g/ml, we have found it desirable to use a mixture of liquids. The final liquid was composed of bromoform with a density of about 2.890 g/ml, n-hexanol with a density of about 0.819 g/ml, and n-pentanol with a density of about 0.817 g/ml. By varying the proportions of these component liquids, it is possible to adjust the density of the mixture to about that of the crystal being investigated when its density lies within the above-stated range.

For example, in the work on potassium chloride,[4] which has a density of 1.98715 g/cc at 25° C., a satisfactory suspension liquid was found to have the following composition: bromoform, 40.00 ml; n-hexanol, 16.94 ml; and n-pentanol, 16.00 ml. This suspension liquid was prepared as follows: bromoform (boiling point range, 150°-151° C.), U.S.P. IX, was washed with water, dried with calcium chloride, and distilled under vacuum. The middle third of the distillate was collected in a receiver which contained a small amount of n-hexanol and n-pentanol (25 drops of each). After distillation, further amounts of n-hexanol and of n-pentanol were added to achieve the desired composition.

The density of this suspension liquid was found to remain constant within the experimental limits of error ($\pm 5 \times 10^{-6}$ g/ml) of the density determination for a period of about seven days. The mixture was easily corrected for small density changes by frequent checks against the suspension temperatures of "standard" crystals suspended within the time of little or no density change. Discoloration of this liquid in sunlight was gradual, and no appreciable solubility of potassium chloride in the mixture was detected when a portion of the liquid was evaporated on a watch glass after it had been in use for twelve or more crystal suspensions.

The density of the suspension liquid at different temperatures was determined by means of hydrostatic weighings. A Pyrex glass bob about 9.4 ml in volume, partially filled with mercury for additional weight, was weighed in air, in water, and in the suspension liquid at different temperatures. To eliminate surface tension effects[8] at the point of entrance of a 0.01" platinum sus-

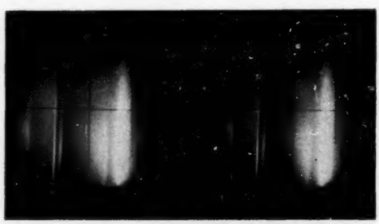

Figure 3. Telescopic view of a crystal of KCl when the bath temperature was below (left view) and above (right view) that of the suspension temperature of the crystal.

pension wire into the liquid, an auxiliary mercury-weighted Pyrex bob about 1.1 ml in volume was attached to the lower end of the suspension wire. The large bob was detachable from the auxiliary bob.

Two series of weighings were made in water and in the suspension liquid, those of the wire suspension with the auxiliary bob immersed and those of the wire suspension with the auxiliary bob and large bob immersed.

The precise volume of the bob was determined by weighings in air and in triple-distilled water which had been heated to expel dissolved gases. Twenty sets of weighings were made in water at temperatures varying from 26.174° C. to 27.769° C. These twenty, independent volume determinations yielded an average bob volume of 9.41336 ± 0.00002 ml when corrected to 25.000° C. by use of the cubical coefficient of thermal expansion of Pyrex glass.[9] The densities of the water at the various temperatures were obtained from the *International Critical Tables*.[10] The average deviation from the mean of the twenty volume determinations was ± 0.00001 ml, and the extreme deviation was −0.00009. The necessary corrections were made for buoyancy in air (applied to the brass weights in all weighings and to the Pyrex bob for the weighings in air) and for the thermal expansion of Pyrex.

The temperatures at which weighings were made were determined with a Beckmann thermometer graduated in 0.01° intervals. The scale of this thermometer was shown to be quite uniform by the U. S. Bureau of Standards calibration. A standard, mercury-in-glass thermometer with a temperature range of 18° to 28° C. and with graduations in 0.01° intervals, the scale of which had been calibrated by the U. S. Bureau of Standards, was compared with the Beckmann thermometer at nine different temperatures at 0.5° intervals over a temperature range of 1° to 5° Beckmann.

The densities thus determined for the bromoform suspension mixture which was used in determining the density of potassium chloride[4] are given in column two of Table II at temperatures covering the range 25.027° C. to 29.320° C.

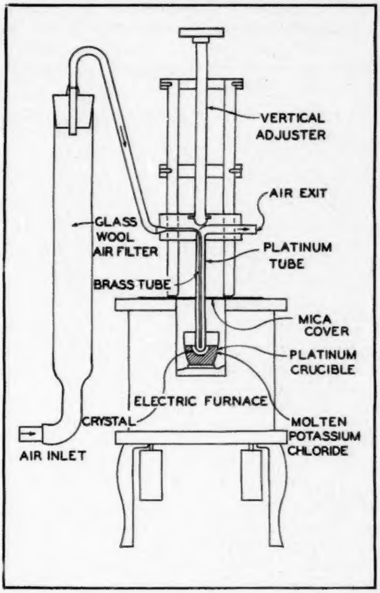

Figure 4. Apparatus for growing crystals of KCl.

PREPARATION OF CRYSTALS FOR ANALYSIS

Crystals used in determining densities must be as chemically pure as possible in order to provide precise results. The reader is referred to original papers[1, 2, 4] for details of the rigorous purification procedures.

Many crystals for density analysis can be prepared from their melts. For instance, potassium chloride crystals were prepared by fusion in a platinum crucible heated by an electric furnace to about 75° above the melting point. Crystallization was produced about the tip of a closed platinum tube inserted into the melt. The apparatus for this step is diagrammed in Figure 4. To produce crystallization, the tip of the 6 mm OD

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[8] Osborne McKelvey, and Bearce, *Bull. U. S. Bur. Stand.*, Reprint No. 197 (1912).

[9] R. M. Buffington and W. M. Latimer, *J. Am. Chem. Soc.* 48, 2305 (1926).

The cubical expansion coefficient was taken as three times the linear coefficient, given as 3.6×10^{-6} at 300° K.

[10] *International Critical Tables* (McGraw-Hill Book Company, Inc., New York, 1928), Vol. III, p. 25.

TABLE II
DENSITY OF SUSPENSION LIQUID*
AS FUNCTION OF TEMPERATURE

Temperature, °C.	Density, g/ml.
29.320	1.98422
29.068	1.98468
28.819	1.98515
28.547	1.98567
28.304	1.98611
28.048	1.98661
27.806	1.98706
27.543	1.98756
27.310	1.98799
27.060	1.98846
26.802	1.98894
26.556	1.98940
26.301	1.98989
26.072	1.99032
25.794	1.99084
25.553	1.99128
25.289	1.99178
25.027	1.99229

* Bromoform mixture, used in determining the density of KCl. The bob volume at 25.000° C. was taken as 9.41336 ml. and corrected to the temperature of each weighing by means of the cubical coefficient of thermal expansion of Pyrex.

platinum tube was lowered a short distance into the melt by means of the adjusting screw, then the temperature of the furnace lowered slowly while a slow stream of air was passed through the tube. When the crystal that formed had reached a convenient size, it was withdrawn from the melt and held a short distance above the surface of the potassium chloride in the crucible while the furnace was slowly cooled, over a period of several hours, to room temperature.

Because of the difference in expansion coefficients of the platinum and the potassium chloride, the hemispheric crystal formed then split into radial segments. Segments were selected and annealed for four hours at about 50° below the melting point and then were gradually cooled over a period of four hours to room temperature. It was found necessary to store these crystal segments in vacuum over phosphorus pentoxide in order to get reproducible densities. Evidently, the components of the atmosphere affect the surface of the crystals.

By this method of crystal suspension, the density can be determined to between one or two parts in 100,000. Typical is the result obtained for potassium chloride; namely, 1.98715 ± 0.00003 g/cm³.

CALCULATION OF THE ATOMIC WEIGHTS

Let us take as an example of the atomic weight calculations the computation of the atomic weight of fluorine from the density and X-ray data for potassium chloride and lithium fluoride. Equation (1) from the introduction becomes in this case,

$$M_F = \frac{p_{LiF} Rg^3 \, F \, M_{KCl}}{p_{KCl}} - M_{Li} \quad (2)$$

Rg has been computed from the X-ray data for the two crystals and found to be 0.63986. F, the structure factor, is equal to unity in this case. We have determined the densities to be 2.64030 g/cm³ and 1.98827 g/cm³ for lithium fluoride and potassium chloride, respectively.

The molecular weight of potassium chloride has been found through chemical determinations to be 74.5530 and the atomic weight of lithium to be 6.9390. Thus, having evaluated all the quantities in the right member of equation (2), we find the atomic weight of fluorine to be 18.9967.

A number of such computations, utilizing the data on a number of crystals, have been used to obtain atomic weights. We have found the atomic weight for calcium to be 40.0849 ± 0.0030 and that for fluorine to be 18.9967 ± 0.0013. For details of these atomic weight calculations, the reader is referred to the original article.[5]

CONCLUSIONS

If the density and X-ray data for certain crystals are used to calculate well known chemical atomic weights, it is possible to obtain excellent checks between the chemical atomic weights and the calculated values. In view of these close correlations as well as the method employed in these atomic weight computations, considerable credence can be attached to the calculated X-ray-density-chemical atomic weights.

It is apparent that the determination of atomic weights from the comparison of molecular weights by combination of density and X-ray data is as reliable as other standard atomic weight procedures.

GEORGIA TECH RESEARCH INSTITUTE

By **GERALD A. ROSSELOT**
Director, State Engineering Experiment Station
and **HARRY L. BAKER, JR.**
President, Georgia Tech Research Institute

In recent years, the volume of industrial research and development conducted at Georgia Tech has reached such proportions as to dictate the necessity for correlating this endeavor through a central agency—preferably a corporate body which can assume contractual obligations. In order to meet this need, the Georgia Tech Research Institute has recently been organized as a successor to the earlier Industrial Development Council, which was formed several years ago to serve a similar end.

It is the purpose of the Institute to implement and coordinate the utilization of Georgia Tech research facilities by those industries, associations, government agencies, or individuals who may require these services in the search for new or better products, in the development of technical processes, or in the prosecution of fundamental research.

The Institute is a nonprofit organization, separately incorporated under the laws of the State of Georgia and closely integrated with the Georgia School of Technology. Its board of trustees consists of four members selected from the Georgia Tech faculty, four members from the Georgia Tech alumni organizations, and four members from industry at large. The present Board of Trustees is comprised as follows: Preston Arkwright, Chairman of the Board, Georgia Power Co.; Fuller E. Callaway, Jr., President, Callaway Community Foundation; Cherry L. Emerson, Dean of Engineering, Georgia School of Technology; M. A. Ferst, President, M. A. Ferst, Ltd.; Frank A. Hooper, Jr., Judge, Superior Court, Atlanta Circuit; Raymond A. Jones, Vice President, J. A. Jones Construction Co., Inc.; Frank H. Neely, Chairman of the Board, Sixth Federal Reserve District; Gerald A. Rosselot, Director, State Engineering Experiment Station, Georgia School of Technology; Robert I. Sarbacher, Dean of Graduate Division, Georgia School of Technology; Blake R. Van Leer, President, Georgia School of Technology; Robert H. White, Jr., President, Southern Wood Preserving Co.; and

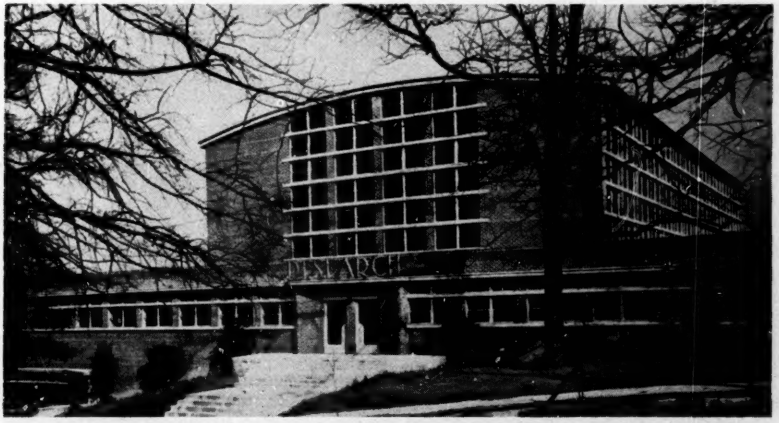

Figure 1. Front view of the Research Building at the Georgia School of Technology.

George J. Yundt, Retired Treasurer, Southern Bell Telephone and Telegraph Co.

The officers of the Institute are Fuller E. Callaway, Jr., Chairman of the Board; Blake R. Van Leer, Vice-Chairman of the Board; Harry L. Baker, Jr., President; Gerald A. Rosselot, Director of Research and Secretary; and Cherry L. Emerson, Treasurer.

FACILITIES

Normally, the research and development work on projects which the Institute accepts is conducted through use of the research facilities of the Georgia School of Technology. However, the charter of the Institute permits it to enlist such other assistance as may be required.

Industrial research and development on the campus of Georgia Tech are directed by the State Engineering Experiment Station, whose modern Research Building contains the special laboratories, pilot plant floor, machine shops, design department, and other installations required to supplement the research facilities of the School.

In the prosecution of industrial research and development, the Station has available and utilizes the extensive technical facilities of the departments of Aeronautical Engineering, Architecture, Biology and Public Health Engineering, Ceramic Engineering, Chemistry, Chemical Engineering, Civil Engineering, Economics and Social Science, Electrical Engineering, Engineering Drawing and Mechanics, Geology, Industrial Engineering, Industrial Management, Mathematics, Mechanical Engineering, Physics, Psychology, and Textile Engineering.

The School library, one of the finest and most complete collections of technical books and journals in the country, affords a primary tool for research. All of these facilities will be coordinated by the State Engineering Experiment Station and made available on a contractual basis through the services of the Georgia Tech Research Institute.

PERSONNEL

The research staff of the Institute, through its relations with Georgia Tech, includes the full-time staff of the State Engineering Experiment Station and its faculty advisors, associates, consultants, assistants, and technicians. Thus the Institute has available trained engineers and scientists who are engaged in full-time research; faculty members of all the departments of Georgia Tech, men who are highly trained in their various fields of technology; graduate students who may use their technical proficiencies in applied research while they gain additional scientific training; and technicians who are trained to perform the various routine tasks required for the successful prosecution of research.

CONTRACTUAL RELATIONS

The officers and staff of the Georgia Tech Research Institute are available for consultation with anyone interested in utilizing the research and development facilities of Georgia Tech. All discussions of such programs are held in complete confidence. When preliminary discussions yield a mutually-satisfactory understanding, a contract is then executed between the Georgia Tech Research Institute and the organization or individual.

The sponsor of research at Georgia Tech is completely protected on patent rights, which may be exclusively assigned to him. Adequate Institute - employee agreements, proper notebooks and record procedures, a strict policy of avoiding conflicts of interest, and close contact with patent counsel are instruments through which such protection is maintained.

Regular reports of progress and findings are rendered during the period of each contract. Upon termination of a contract, a final, detailed report is submitted.

Each contract specifies a maximum expenditure for the term agreed upon in the course of definition of the project. Expenses are payable monthly upon submission of a statement and include the following items: (a) actual sums paid as compensation to the Institute's staff and agents who are employed on the project; (b) costs of special equipment, supplies, travel, and other directly-chargeable incidental expenses; and (c) a fixed percentage of item (a) to cover overhead and administrative expenses involved in the performance of the project.

PUBLICATION

The Georgia Tech Research Institute believes that outstanding scientific achievements should be reported, since only in this manner can the storehouse of available information be replenished and the merit of

the School and its staff be properly assessed. Consequently, it urges the publication of such material wherever feasible. Since secrecy is obviously required on certain types of projects, however, the Institute will contract to hold all information confidential until publication is mutually agreeable.

Although the Georgia Tech Research Institute has been activated only recently, promising results have already been obtained. It is anticipated that this organization will be instrumental in developing mutually-beneficial relations between industry and the Georgia School of Technology.

ENGINEERING CONTROL OF WELDING HAZARDS

By G. W. REID*
Georgia School of Technology
and N. V. HENDRICKS
Georgia State Department of Health

Welding, today, is a tremendously important tool of industry, its use having been given great impetus by the recent necessity for unprecedented production of war material. In ship building, for example, welding makes possible quicker and lighter construction through direct displacement of rivets. In aircraft production, countless welds are required on parts made of such diverse materials as stainless and galvanized steel, iron, and aluminum.

Since the war, the demands of the reconversion effort have continued the trend toward increasing welding use. New and different materials, and metals with coatings of various types are now being welded; new fluxes and coating rods have been introduced. All these developments have given emphasis to new engineering problems which are commonly not recognized as such; namely, industrial health hazards arising from welding and cutting operations.

The engineering problems concerned are those of control of the environmental health factors which accompany the various welding operations. It has been found that the most common types of welding, gas and arc, provide most of the hazards, while resistance, atomic hydrogen, and thermite welding are not as extensively used, or as dangerous. During the war, however, considerable disability varying in severity from light absenteeism to death was directly attributable to the lack of engineering control over the unfavorable environment created by all these types of operations.

There are several definite kinds of injuries which can result from the various types of welding: (a) eye flash burns, (b) skin burns, (c) metallic poisonings, (d) metal fume fevers, and (e) injuries from toxic gases. All of these hazards can be anticipated and controlled.

BURNS

Eye flash burn is a common problem in arc welding and is associated to a certain extent with other types of welding procedures. The ultraviolet light produced by the welding arc is capable of causing severe eye burns so that, when an individual is exposed to this light, or to flashes, burns of this nature are likely to result. Skin burns, which may also result from the light produced by the arc, are quite similar in nature to common sunburn, although they may be considerably more severe and, in some cases, are directly responsible for absenteeism. As is the case for sunburn, workers quite frequently receive considerable exposure before realizing the extent to which they are being burned. The intense heat which is associated with atomic hydrogen welding is also a hazard.

METALLIC POISONINGS

When welding is done on alloy metals which contain such toxic components as lead, cadmium, and the like, definite health hazards are produced by the volatilization of those metals; for example, in the welding of steel which has been treated for malleability with lead. This is also true where

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welding, burning, or cutting is performed on surfaces which have been coated with toxic materials, such as paints containing lead or plated surfaces which contain cadmium. In the aircraft industry, considerable welding is performed on stainless steel, causing small concentrations of cadmium to be produced.

Exposure to lead fumes was frequently encountered during the construction of "Liberty Ships." It was the practice in these shipyards to apply a basic coat of red lead paint, then follow this with a finishing coat. In many instances, tack welding was then performed on these surfaces. Obviously, since the red lead component of the paint was easily converted to the oxide and metal by the welding operation, innumerable cases of exposure to lead fumes were occasioned.

Toxic metals such as lead are rather striking in their action and, unless recognized and controlled, will cause serious results. The toxicity of the individual metals, of course, varies considerably, as do the physiological effects caused by exposure to them; see Table I.

METAL FUME FEVERS

Metal fume fever, commonly referred to by welders as "zinc shakes," "brass shakes," or "galvo," is usually caused by the inhalation of zinc oxide in the form of welding fumes. It can be also caused by the fumes of antimony, copper, magnesium, tin, and nickel.

TABLE I

MAXIMUM ALLOWABLE CONCENTRATIONS OF INDUSTRIAL ATMOSPHERIC CONTAMINANTS COMMONLY ENCOUNTERED IN WELDING*

Contaminants	Ppm.	Mg/M³
Carbon dioxide	5,000	10,000
Carbon monoxide	100	100
Fluorides	...	1
Iron oxides	...	30
Lead	...	0.15
Magnesium	...	15
Manganese	...	6
Nitrogen oxides	25	100
Ozone	1	2
Zinc oxides	...	15

* Warren Cook, *Industrial Medicine 14*, 11 (November, 1945).

Metal fume fever is a temporary condition, and there exists no evidence of any permanent injury. The symptoms are aches, pains, chills, and fever, beginning approximately six hours after exposure. Mild cases of metal fume fever were experienced in the aircraft industries by welders working on zinc, iron, and aluminum. Some cases were further complicated by effects from the cadmium in stainless steel parts and the fluorides in the fluxes.

In the construction of ships, most of the welding is of the arc type, hence the resulting metallic fumes in the atmosphere are oxides of iron. However, in the fabrication of war ships, Navy standards require that a considerable portion of metal used must be galvanized. Thus the problem becomes complicated because of the ease with which the zinc in the galvanized coating is oxidized and dispersed into the atmosphere. Much absenteeism among welders was directly attributable to this exposure and to the resulting metal fume fevers.

TOXIC GASES

An electric arc has the ability to break down the normal constituents in the atmosphere, forming oxides of nitrogen. Some of these oxides are highly toxic compounds and, when inhaled, may produce lung edema. In this instance, such lung edema is caused by the inhalation of NO_2, which combines with the moisture of the upper respiratory system to form nitric acid. This acid, in turn, produces marked irritation of the surfaces of the lower respiratory system and the lungs proper. To counteract this, the lung tissues flood with fluid and, if the patient does not rest immediately, this flooding will create such a load as to lead to suffocation. This poisoning is particularly insidious, because there is a time lag of several hours between the exposure and the development of clinical symptoms. The problem of nitrogen oxide welding hazards becomes of special importance where arc welding is carried out in confined spaces, such as in tanks

Another gaseous product from welding is carbon dioxide, produced by oxidation of the organic matter included in the coating of certain types of welding rods, in which this organic material serves as reducing agent for the actual weld. The importance of carbon

dioxide associated with welding is not too great, since it is only in very rare cases that atmospheric concentrations of carbon dioxide reach a point where they may be considered significant from a health standpoint. Ozone is also generated by the electric arc, but this dissipates very readily and is little more important than carbon dioxide.

The incomplete oxidation of carbonaceous material in the coating of welding rods produces small quantities of carbon monoxide. The likelihood of toxic concentrations being produced, however, is rather remote. Because of its extreme toxicity, however, carbon monoxide (which has an affinity 300 times that of oxygen for the red blood cells) is potentially a factor which should be considered in determining the safety of the working environment.

The flux materials used in welding compounds and rod coatings contain fluorides. Upon burning of the rod, these fluorides are dispersed into the atmosphere, where they may become concentrated in the respiratory tract of the individual doing the welding. Fluorides are highly irritating to these passages, and they produce much discomfort to the welder, if not actual disability.

Manganese is used in welding rods, but its fumes seldom reach the Maximum Allowable Concentration. Experimental data and also practical observations have indicated Maximum Allowable Concentrations for zinc oxide and other metallic contaminants in the atmosphere (see Table I). Laboratory animals have proved helpful, but these limits must, in the final analysis, be determined on human beings.

CONTROL METHODS

There are four logical methods of controlling welding hazards: (1) general ventilation, (2) local or point exhaustion, (3) personal protective devices, and (4) substitution of non-toxic substances or processes. For protection against eye burns, special goggles should be worn. Welders' helmets contain heavily-tinted glasses for protection of the welders' eyes; unfortunately, however, it is not the individual welder who receives the eye burns, but rather someone in the vicinity of the arc. In addition to general use of eye glasses, shields should be placed around the welding operation, so that it is isolated from the surrounding area, thus precluding the possibility that other men in the immediate area will be exposed to the arc. Skin burns may be avoided to a certain extent by the wearing of proper clothing.

Respirators provide good personal protection and are frequently used on welding operations, but those employed should be designed and approved for the particular exposure. The chief difficulty with common respirators lies in the fact that it is a problem to secure the cooperation of the welders in wearing them. Also, it is difficult to convince welders of the necessity for regularly replacing the used filters. As mentioned, respirators are more or less limited to the selective protection which they afford. In other words, a respirator designed for protection against toxic fumes or even toxic metals, such as lead or cadmium, would be of little value against the nitrogen oxides. Therefore, it is obvious that respirators, unless of a supplied air type, cannot be depended upon for complete protection. In addition, respirators must be frequently washed and sterilized, a difficult operational procedure. When a plant is large enough to have one man assigned to the task, however, the protection respirators afford can be better utilized.

In a large plant which contains many departments doing welding, some sort of a check should be maintained, perhaps through the purchasing department, on the use of new materials and substitutes. This check can be used to introduce control procedures and to stimulate the use of less toxic materials.

General ventilation is sometimes applied to the control of welding hazards. Here the theory is one of dilution, a sufficient amount of air being introduced into the atmosphere until the atmospheric concentration of the entire room is below the toxic level. The weakness in this procedure lies in the fact that welding fumes, gases, and the like are concentrated in the immediate area where the welding operation is being performed. For this reason, it is evident that any type of general dilution based on the volume of the entire room is not effective in controlling or preventing toxic concentration in isolated areas, particularly at the point of generation.

The most effective method of controlling exposures incident to welding lies in the application of local or point exhaust venti-

lation. By local exhaust ventilation is meant the removal of atmospheric contaminants at the point of generation or dispersion by means of a suction device. Considerable study has been made of this individual problem, and data have been developed which indicate the aerodynamic considerations necessary for the proper control of the welding fumes. The actual amount of air handled will be dependent upon the type of welding done and upon the physical conditions under which it is carried out. In general, however, with heavy welding such as is done in the production of fabricated parts, ships, and the like, a sufficient amount of air must be handled to produce a linear velocity across the point of welding of not less than 200 feet per minute. It is for this reason that local or point exhaust ventilation is much more economical than general ventilation.

In most cases, the end of the suction line can be held within six to eight inches of the point of weld, so that this distance becomes the determining factor. From the practical standpoint, it has been found that 200 to 250 C.F.M. handled through a four inch flexible hose will do a satisfactory job in controlling the volatile products from arc welding. To increase the efficiency of the collecting device, it is advantageous to provide the end of the hose line with a small suction hood, or flange. If the hood or opening interferes with the work, however, as for example in bench welding, the opening may be incorporated into a grill and the work performed on it.

The characteristics of such a collecting device fundamentally follow the mathematical expression:

$$Q = V^{10X^2+A}$$

where Q is cubic feet of air handled, V is linear velocity at point X, X is the distance measured in feet, and A is the area of the hood expressed in square feet. From this equation, it is obvious that intelligent use of collecting devices is important, with particular reference to placing and maintaining the suction line within the required distance of the point of weld. As an approach to controlling metal fume fever in shipyards, local exhaust ventilation was provided for welding operation on the ways during actual shipyard construction, and also for prefabrication before the partially-assembled parts reached the ways. By applying local exhaust ventilation, the exposure to metallic oxides was avoided.

Diseases such as metal fume fever are "man made," and it is of prime importance that engineers be aware of these hazards and take the necessary steps to protect workers before disability occurs.

REPORT FROM THE LIBRARY

By DOROTHY M. CROSLAND
Librarian, Georgia School of Technology

This is a report on the library for the war years—a report of progress to the students and alumni. Many of you have been to the far ends of the earth, and now you are back—some in school and others on jobs of engineering or research. It is well that you know something about the library's increased acquisition of important engineering and scientific journals. A great reservoir of research materials is being built to serve not only the students and faculty of Georgia Tech, but also the engineers of this state and, eventually, of this entire region.

Those of you who have returned and who knew the library only from its physical

appearance will find its exterior unchanged. It is the same small building that was opened in October, 1906, to serve 562 students and 25 faculty members, although a small addition (for stacks) was added in 1932. The interior, you will find, has been changed only by the addition of new sections of book shelves, which make the building so crowded that it fairly bulges at its sides. The same 1906 building now serves approximately 3500 students, 200 faculty members, and the staff of the State Engineering Experiment Station. You, then, who knew the library by its physical appearance, will see no change on the exterior, and you will be conscious only of the crowded conditions inside.

Those of you who knew the library by its collection, however, will be aware of great improvements. You will be pleased to know that many times now you can find not only the abstract of an article, but also the original. Many complete journals, both foreign and domestic, have been added. The library has approximately 75,000 volumes and currently receives about 1200 journals.

Through the generous gifts of one of the large foundations, we are continuously enlarging our collection in order to support graduate work and research in engineering fields. Our list of desiderata is still large, however, and it is becoming more and more difficult to find complete files of journals, both because of shortages caused by the recent war and because many industrial concerns are enlarging their libraries. The competition for engineering and scientific journals is very keen. However, we must continue our progress if we are to take our place as *the* engineering library of the South, since Georgia Tech is the natural center for engineering research in the Southern region.

Plans are now being prepared for a new, air-conditioned library building capable of housing 500,000 volumes and seating approximately 1,000 students. Space will be provided for both undergraduate and graduate students, and small rooms will be available for research engineers. We are planning patent, map, and film collections, and we shall also have microfilm services. In addition, space for music is being planned.

To this point, I have told you only about the library, its physical appearance and its plans for the future. Beginning with the next issue of THE RESEARCH ENGINEER, I am going to list some of our important acquisitions since 1939. This should prove of interest since, if you are an alumnus of Georgia Tech, you may use the books and journals in the building. Indeed, we hope that our alumni will become reacquainted with our library, so that they, as well as our present students, will know its real value to science and technology.

Our library now has all of the more important encyclopedias, treatises, handbooks, and periodicals devoted to engineering and science. We have added some of our most valuable journals since December, 1939, when we received our first donation from the General Education Board.

We are one of the few libraries that can boast a complete file of *The London, Edinburgh and Dublin Philosophical Magazine and Journal of Science*, 1798 to date. We have added the important publications of the Royal Society of London: the *Proceedings*, 1800 to date; the *Philosophical Transactions*, 1849 to date (with some earlier volumes back to 1665); and the *Catalogue of Scientific Literature*. We are pleased that our library has complete files of the *Bulletin de la Societe Chimique de France* (1858 to date); the *Annales de Chimique et Physique* (1789, a few missing volumes in Series I); *Chemisches Zentralblatt* (1831 to date); *Compte Rendus Hebdomadaires des Seances de l'Academie des Sciences* (1835 to date); and the *American Journal of Science* (1818 to date). The *Chemical Abstracts* of the American Chemical Society, the *British Chemical Abstracts*, the *Biological Abstracts*, and the *Science Abstracts* are also complete. *Beilstein's Handbuch der Organischen Chemie, Gmelins Handbuch der Anorganischen Chemie, International Critical Tables*, and *Landolt-Bërnstein's Handbuch der Organischen Chemie* are important treatises to the research chemist.

It is our hope that this series will help to make our library a tool in your search for knowledge and in your industrial applications thereof.

WHAT WOULD YOU LIKE?

Bulletins of the nature of THE RESEARCH ENGINEER can and do contain features of many types. The problem of selecting a sufficient number to fill any given number of pages is not particularly difficult, nor is it any problem, in a School as large and diversified as Georgia Tech, to secure articles on a desirable variety of subjects.

As mentioned on the title page, however, it is our desire to make this *your* bulletin, to publish articles and include departments on topics of interest and utility to alumni, faculty, and industry. For this reason, we will more than appreciate your comments on our plans and an indication of your willingness to cooperate in making this bulletin worthy of publication.

In addition to articles dealing with the industrial research projects of the State Engineering Experiment Station and the fundamental research work conducted by the Station, the Department of Graduate Studies, and individual faculty members, we plan to publish feature articles on engineering and research topics which are within the fields of specialization of the Station's staff, the faculty of the School, and the Georgia Tech alumni. Still further, we hope to institute a program by which our readers can become acquainted with the various industries of Georgia and the Southeast, and in this connection we shall from time to time publish descriptions of these industries and, more particularly, of the companies engaged in them. Where possible, we hope that these articles will be written by those Georgia Tech alumni who are engaged in the fields in question.

When a topic seems of sufficient importance to warrant its full exploration, we plan to publish symposia which will serve to add to our useful information. Such symposia may deal with an industry, with a material, or with a field of science. They may report the coordinated programs of technical meetings held at Georgia Tech. In any case, every effort will be made to present the opinions of qualified members of the field, and here again we look to alumni support.

Occasional articles will be prepared on happenings in the Station and School which are of definite importance to the technical development of the area. The two articles on research in this issue are examples; others will deal with details of the Station's expansion, our A. C. Network Calculator, our electron microscope, etc. Economic studies will occasionally be prepared on topics of importance to Georgia and the Southeast.

In regard to editorial departments or series, several are being considered. In this issue appears the first installment of "Report From the Library," which we know will serve a number of important purposes. A "Question and Answer" page may be added to future issues, since the Station is frequently called upon to answer many questions which are of interest to more than the person or company in question. Confidence often has to be observed, of course, but this will not prevent the inclusion of many pertinent questions.

The presence at Georgia Tech of such an excellent library and the existence, at the Station, of a Technical Information Division suggests still other informational departments. Critical reviews of important scientific books seem a logical inclusion. Bibliographies on pertinent subjects will often be available and may sometimes warrant the use of considerable space; these might prove of particular utility to alumni engaged in reestablishing themselves in technical industries following service in the recent war. Current literature surveys are a possibility. Brief editorial notes will certainly appear on a variety of topics.

We promise that your cooperation will never become a burden to you, but we do want to feel that we can call upon you to contribute your advice or to prepare an occasional article when the subject at hand is in your field.

Comments and requests from industrialists are cordially invited. Service to industry is the prime function of industrial research, and it is our desire to make THE RESEARCH ENGINEER a useful tool in this field.